A COMPARATIVE STUDY OF THE SHOULDER REGION OF THE NORMAL AND OF A WINGLESS FOWL

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ELEVEN FIGURES (THREE PLATES)

INTRODUCTION

Among a lot of Rhode Island Red chicks hatched in an incubator by Dr. Fred Sumner Smith, of Chester, Connecticut, appeared one male individual entirely destitute of wings. This was reared to maturity, and lived for nearly two years, forming the subject of an extensive breeding experiment by Prof. Wesley R. Coe. (The results of this experiment will be the subject of a separate paper.) After the death of this bird his body was preserved in alcohol, and later handed over to the writers for a study of the modifications of the muscular and skeletal structures which might be correlated with the congenital absence of wings.

The writers knew of no connected, detailed account, in the literature, of the anatomy of Gallus domesticus, so, with the aid of the brief references available, a study of the normal musculature and skeleton has been carried out on normal fowls of the breed of the wingless rooster. This study has been limited to the shoulder and thoracic regions, as examination of the wingless specimen revealed no abnormalities elsewhere.

No special study of the nerves and blood vessels of the shoulder region was made, but as on the wingless rooster a number of large nerves and blood vessels were found coming from the body cavity and breaking up into small branches to enter the thick

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fascia and skin which covered the area where the wings would normally have been, it may be safely assumed that these were the blood vessels and nerves normally destined to go to the wings, in the absence of which they terminated in the skin and underlying fascia. The normal innervation of the shoulder region of the hen has been described and the nerves figured by Fürbringer ('88). The muscles have been described in the present paper in an order based on their nerve supply, a scheme used by Gadow ('91).

All the variations appearing on the wingless rooster and described below were symmetrical on the two sides of the body unless otherwise stated.

MUSCULATURE

Rhomboideus superficialis (figures 6 and 7; 10 and 11)

Normal. This muscle takes its origin from the rib-bearing cervical vertebrae and from the crests of all of the fused thoracic vertebrae except the most posterior one. It is a very broad muscle, but made up of short fibers, its insertion being along the dorso-lateral surface of the scapula, from the posterior extremity to a point almost directly above the scapular tubercle of the coracoid, and extending ventrally to the dorsal margin of the origin of the scapuli-humeralis posterior.

Wingless. The superficial rhomboid muscles of the wingless rooster were much thinner than the normal, and showed decided variations as to origin and insertion on both sides. On the right side this muscle had its origin limited to the median third of the fused thoracic vertebrae, and its insertion on the dorsal border of the scapula was limited in a similar way. The left rhomboideus superficialis had an origin extending from the crest of the most posterior cervical vertebra to the posterior extremity of the crest of the fused thoracic vertebrae, while its insertion extended from the anterior extremity of the scapula to within a quarter of an inch of the posterior extremity of that bone.

Rhomboideus profundus (figures 7 to 11)

Normal. The deep rhomboid muscle arises immediately beneath the line of origin of the superficial one, but the origin of the deeper muscle extends one vertebra further, both anteriorly and posteriorly. Its insertion is on the medial surface of the scapula from the posterior extremity of that bone to a point about opposite the anterior limit of the superficial rhomboid, and from the dorsal margin ventrally for about the same distance as the superficial muscle.

Wingless. On the abnormal bird the chief variations in the rhomboideus profundus were the extension of its origin posteriorly to the anterior margin of the ilium, and a restriction of its insertion on the scapula to an anterior limit opposite the space between the first and second cervical ribs. These variations were bilateral.

Serratus profundus (figures 7 to 11)

Normal. The serratus profundus is a very narrow, thin muscle whose fibers arise from the tip of the first cervical rib, and thence pass in an antero-dorsal direction to insert on the medio-ventral border of the scapula. The posterior margin of this muscle is closely applied to the anterior margin of the serratus superficialis anterior.

Wingless. This muscle on the wingless rooster was normal as to position and relations, but was at least twice as broad and thick as on the normal bird.

Serratus superficialis anterior (figures 6 to 11)

Normal. The anterior superficial serratus muscle is a broad, thin band, arising from the lateral side of the ventral extremity of the second cervical rib, and inserting just posterior to the serratus profundus on the medio-ventral border of the scapula. The fibers run in an antero-dorsal direction.

Wingless. On the wingless rooster the origin of this muscle was more extensive than usual, and, on account of the second cervical rib of this bird having retained its embryonic sternal

segment, the origin was along the antero-lateral border of the vertebral segment of this rib. The upper limit of origin was opposite the base of the uncinate process. The muscle itself possessed more than the usual number of fibers, rendering it much thicker than the normal, but without increasing its breadth. The insertion on the scapula was normal.

Serratus superficialis posterior (figures 8, 10 and 11)

Normal. The posterior superficial serratus muscle consists of two slips, one arising from the dorsal third of the postero-lateral border of the second cervical rib, the other arising in approximately the same place on the first thoracic rib. Both slips are broad and thin. The fibers run in a postero-dorsal direction, those of the two slips becoming indistinguishable where they lie side by side. The insertion of this muscle is along the median ventral border of the scapula from a point opposite the anterior margin of the second thoracic rib posteriorly to a point opposite the anterior margin of the third thoracic rib.

Wingless. The origin, insertion, and topographical relations of this muscle were normal, but the muscle fibers were so few in number that it was almost reduced to a fascia.

Sterno-coracoideus (figures 10 and 11)

Normal. This is a very short, broad muscle taking its origin from almost the entire lateral surface of the anterior lateral process of the sternum and inserting on the adjoining margin of the coracoid. It lies mediad of the membrane stretched between the coracoid and the anterior lateral process of the sternum, and some of its fibers inosculate with this.

Wingless. Same as normal.

Latissimus dorsi (figures 2, 6, 7, 9 to 11)

Normal. The latissimus dorsi arises (1) from the mid dorsal line, starting with the neural crest of the most posterior cervical vertebra and extending posteriorly over the crest of the first thoracic vertebra; (2) this muscle also has a line of origin from the anterior margin of the ilium. The fibers from the iliac origin

run almost straight anteriorly over the surface of the superficial rhomboid muscle until they inosculate with those coming from the vertebral origin; the combined fibers then run in an antero-ventral direction to their insertion on the ventral surface of the humerus, somewhat posterior to the pneumatic foramen and alongside of one origin of the triceps.

Wingless. The wingless rooster showed the two separate points of origin of the latissimus dorsi, but the fibers from the two places never united, both sets running in a general ventral direction to inosculate separately with the pectoralis muscles. Furthermore, both points of origin were unusually extensive.

Deltoid major (figures 2, 6 and 10)

Normal. The deltoid major takes its origin from the highest point of the humeral tubercle of the coracoid, and extends a very short distance, as a thick, round bundle of fibers to its tendinous insertion on the superior tubercle of the humerus.

Wingless. The wingless specimen showed no trace of this muscle unless a fascial mass covering the point of union of the three members of the shoulder girdle should be considered as the rudiments of this and the following muscle.

Deltoid minor (figures 2, 6 and 10)

Normal. The deltoid minor arises from the posterior border of the furcular tubercle of the coracoid, and like the deltoid major it is a very short muscle, having its insertion on the lateral surface of the humerus under the superior cristas and embraced by the insertion of the pectoralis major.

Wingless. As mentioned above, in connection with the deltoid major, a thick fascial mass of doubtful significance may represent on this bird both the deltoid muscles.

Scapuli-humeralis anterior (figures 2, 6, 8 and 10)

Normal. This is a small, round muscle arising from the ventro-lateral border of the scapula just anterior to the origins of the subscapularis externus and the scapuli-humeralis posterior. The fibers run almost at right angles to the surface of the scapula to

insert on the ventral surface of the humerus just distal to the pneumatic foramen.

Wingless. On the wingless rooster the scapuli-humeralis anterior was entirely absent on both sides.

Scapuli-humeralis posterior (*figures 2, 6, 7, 9 to 11*)

Normal. The scapuli-humeralis posterior is a broad sheet of muscle arising from the ventral three-fourths of the lateral surface of the scapula, from the posterior extremity of that bone to a point opposite the anterior margin of the most posterior cervical vertebra without a rib. Its fibers run in an antero-ventral direction, and when about in line with the anterior limit of origin they abruptly join a tendon which inserts on the lateral border of the pneumatic foramen between two origins of the triceps. The anterior border of this muscle is overlaid by the latissimus dorsi.

Wingless. On the abnormal rooster the origin of the scapuli-humeralis posterior extended much nearer the dorsal margin of the scapula than on normal specimens. The fibers ran in the usual direction, but ended by fusing with those of the coraco-brachiales and subcoraco-scapulares.

Subcoraco-scapulares (*figures 2, 6 to 10*)

Normal. The subcoraco-scapulares are three muscles, external and internal subscapular and the subcoracoid, arising separately, but grouped together because all three possess a common tendon of insertion. The subscapularis externus arises from the ventro-lateral margin of the scapula, ventral and slightly posterior to the anterior limit of origin of the scapuli-humeralis anterior. The subscapularis internus arises (1) from the medial surface of the scapula from a posterior limit corresponding to the origin of the externus on the lateral surface, anteriorly to the coracoid; (2) from the medial border of the coracoid for a distance of three-quarters of an inch from the ventral margin of the scapula; (3) a few fibers arise from the membrane separating this muscle from the coraco-brachialis anterior. The fibers of the subscapularis externus run ventrally, those of the subscapularis

internus converge to join the tendon common to the three subcoraco-scapular muscles.

The subcoracoideus arises (1) from the ventral third of the medial border of the coracoid; (2) from the medial surface of the furculo-coracoid membrane, which separates it from the coracobrachialis anterior; and (3) from the posterior surface of the anterior median process of the sternum together with the margins of the body of that bone.

The common tendon of these three muscles passes upward across the lateral surface of the scapula to insert on the humerous proximal to the pneumatic foramen, and between the humeral origin of the biceps and the insertion of the coraco-brachialis posterior.

Wingless. The subcoraco-scapulares were represented on the wingless rooster by the subcoracoid and the internal subscapular, the external subscapular being absent on both sides. The origins of the two muscles present differed from the normal in being unusually extensive, the subcoracoideus arising from the whole posterior border of the coracoid, and the origin of the subscapularis internus extending along the medio-ventral margin of the scapula from the anterior extremity of that bone to the normal posterior limit of its origin. Fibers from both these muscles inosculated with fibers of the coraco-brachiales, and there was also a common tendon, not shown on our diagrams, which inserted on the humeral tubercle of the coracoid.

Pectoralis major (figures 2, 6, 7, 10, 11)

Normal. This muscle takes its origin (1) from the ventral quarter of the keel of the sternum throughout its entire length; (2) from the ventral part of the lateral surface of the membrane connecting the furcula and the sternum; (3) from the entire lateral surface of the furcula with the exceptions of a very short distance at its dorsal extremity and of the postero-dorsal angle of its enlarged ventral extremity; (4) from that part of the furculo-coracoid membrane adjoining its origin on the furcula; (5) from the external and internal posterior lateral processes of the sternum and from the membrane joining them to each other,

to the keel, and to the body of that bone; (6) some fibers of the pectoralis major arise from the fascia covering the dorsal border of the pectoralis minor.

The insertion of the pectoralis major is on the upper end of the humerus, under the superior crista.

Wingless. On the wingless rooster the origin of the pectoralis major was considerably reduced, the reduction being in different regions on the two sides of the body. On the right side the origin of this muscle failed to reach the posterior tip of the keel of the sternum while anteriorly it crossed the membrane from the sternum to the furcula, ran up the latter bone for only a short distance beyond its enlarged ventral extremity, and that, except for the membrane stretched between the posterior lateral processes of the sternum is the whole extent of its origin on that side. The left side of the wingless bird showed a normal origin from the keel of the sternum, and from the membrane between that bone and the furcula; on the furcula the origin extended dorsally further than usual but was everywhere limited to the anterior margin of the bone. The only other point of origin of the pectoralis major on the left side was from the dorsal angle of the posterior lateral process of the sternum.

The origins of the pectoralis major muscles of the wingless bird were, however, nowhere near as unusual as were the insertions. On the right side the muscle was saddle-shaped, its fibers inosculating with both the posterior and the anterior portions of the latissimus dorsi. The left side showed a more complex anomaly, the slip of the pectoralis major arising from the external posterior lateral process of the sternum inosculating with the posterior portion of the latissimus dorsi, while the main part of the pectoralis major inosculated with a slip from the anterior portion of the latissimus dorsi, the two parts of pectoralis major appearing to be entirely separate from each other.

On both sides of the body the fibers of the pectoralis major and of the pectoralis minor inosculated anteriorly, and sent dorsally a common tendon which bifurcated just before it inserted on the dorso-lateral border of the scapula, anterior to the origin of the scapuli-humeralis posterior.

Pectoralis minor (figures 2, 6 to 11)

Normal. The pectoralis minor arises (1) from the postero-dorsal angle of the ventral extremity of the furcula, and from the lateral surface of the membrane stretched between that angle, the ventral end of the coracoid, the body and keel of the sternum; (2) from the ventral border of the body and the dorsal three-quarters of the keel of the sternum; (3) from the ventral margin of the membrane between the keel and the internal posterior lateral process of the sternum. The fibers of this muscle converge toward its midline, and its tendon of insertion passes with that of the coraco-brachialis anterior through the foramen triosseum—between the anterior extremities of the furcula, coracoid, and scapula—to attach to the upper end of the humerus at the base of the dorsal surface of the superior crista.

Wingless. On the wingless rooster the pectoralis minor, like the major, showed an origin over a smaller area than the normal, the reduction being more marked on the right side, where no fibers arose from the sternum, the origin being limited to the ventral extremity of the furcula and the membrane stretched between that bone and the sternum. On the left side the origin of the pectoralis minor was practically confined to the ventral half of its normal limits, with the further abnormality of a dorsal extension along the posterior border of the furcula to the extremity of that bone. Inosculations with the pectoralis major were present on both sides, and on both sides of the body there was a small tendinous insertion on the scapula near the scapular tubercle of the coracoid. The posterior portion of the left pectoralis minor inosculated with a slip from the latissimus dorsi.

Coraco-brachialis anterior (figures 2, 6, 8 to 11)

Normal. This muscle arises (1) from the lateral surface of the anterior median process of the sternum, (2) from the ventral half of the medial border of the coracoid, (3) from the lateral surface of the furculo-coracoid membrane bordering the coracoid. The muscle narrows at the dorsal end and its tendon accompanies that of the pectoralis minor through the foramen trios-

seum; it inserts on the anterior dorsal margin of the superior crista of the humerus.

Wingless. On the wingless rooster the usual place of origin of the coraco-brachialis anterior was covered with a heavy fascia, possibly representing this muscle, which ran posteriorly to inosculate with the coraco-brachialis posterior.

Coraco-brachialis posterior (figures 2, 6, 8 to 11)

Normal. The coraco-brachialis posterior arises (1) from the fascia of the pectoralis minor at a point on the dorsal border of that muscle near the sterno-coracoid articulation; (2) from the lateral surface of the coracoid with a ventral limit at the line of articulation of that bone with the sternum and a dorsal limit just ventral to the capsule of the humeral joint; (3) by a narrow slip from the body of the sternum starting anteriorly from the line of articulation of the coracoid and terminating posteriorly at the base of the lateral processes of the sternum.

This muscle runs abruptly into a tendon in the axillary space, and thereafter it joins by slips with the tendon of the subcoraco-scapulares, the two tendons finally separating and that of the coraco-brachialis posterior passing posterior to that of the subcoraco-scapulares and inserting on the anterior end of the humerus proximal to the pneumatic foramen, and embraced by the tendon of insertion of the subcoraco-scapulares.

Wingless. The coraco-brachialis posterior, and possibly some of the anterior as well, was represented on the wingless rooster by a large mass of muscle fibers which arose over almost the entire lateral surface of the coracoid, and passed in a postero-dorsal direction to inosculate with fibers of the scapuli-humeralis posterior.

Biceps brachii (figures 2, 6 and 10)

Normal. This muscle arises by two heads, one a long tendon from the furcular tuberosity of the coracoid, the other a short tendon from the proximal end of the humerus along a lateral line starting distal to the caput, a little ventral to the dorsal margin of the bone, and extending around to the ventral surface,

anterior to the pneumatic foramen, to where the tendon of the subcoraco-scapulares inserts. The head of the biceps brachii which has its origin on the coracoid, passes first over the deltoid minor, then over the base of the broad ligament uniting the coracoid and humerus, to finally join the head arising from the humerus. The insertion of this muscle is on the radius and ulna.

Wingless. Absent.

Triceps cubiti s. anconeus (figures 2 and 10)

Normal. The triceps muscle arises by three heads of which the two tendinous ones, attached to the scapula along its ventrolateral border just caudad of the capsule of the humeral joint, are sometimes (Beddard '98) described as a separate muscle, the anconeus longus. These two tendons, which are oval in section, unite at once, but do not join the third head until near their common insertion on the olecranon process of the ulna and on the capsule of the neighboring joint. The third head of the triceps arises fleshily from a limited area on the humerus just proximal to the pneumatic foramen, and from the greater part of the ventral surface of that bone, exclusive of the articular portions.

Wingless. This muscle was absent from the wingless rooster, but attached to both scapulas in the position of its posterior tendinous origin from that bone were tendons connected with the pectoralis muscles.

SKELETON

The skeleton of the wingless rooster (figs. 4 and 5) differs in its entirety from any of our normal specimens (fig. 3) in being more heavily built; the individual bones are broader and thicker than usual. One notices also that the sternum is more nearly parallel to the vertebral column than in the normal bird of this species, a condition apparently correlated with the more perpendicular position of the coracoid. Aside from these peculiarities the abnormalities of the wingless skeleton are limited to the thoracic region and will be taken up individually.

The vertebrae present no abnormalities.

The ribs show slightly different anomalies on the two sides of the body, the cervicals being the ones affected. On the left side the first cervical rib is unusual in possessing an uncinate process, while the second cervical rib on this side has an incomplete sternal segment. The first cervical rib on the right side likewise has an uncinate process, and the second shows a condition further removed from the normal than its mate on the left side, possessing a complete segment uniting it to the anterior lateral process of the sternum.

The most posterior thoracic rib on the left side appears at some time to have had its vertebral and sternal segments separated so that they slid past each other, and their ends formed a new ligamentous connection between the ventro-median extremity of the vertebral segment and the dorso-lateral extremity of the sternal segment.

The sternum of the abnormal bird is quite aberrant in form, showing a very gradual, instead of an abrupt, transition from the vertical to the horizontal plane at the dorsal margin of the keel, being unusually broad just anterior to its caudad extremity, and having a thick and very short anterior median process. The anterior lateral processes of this sternum are also unusual in their perpendicularity. The dextral curvature of the anterior end of the keel is probably due to many falls the rooster had while this bone was still somewhat cartilaginous.

The shoulder girdles of the wingless bird are both normal to the extent of each possessing the usual three members, in their normal positions. The abnormalities are in the proportions of the separate bones, and in their articular relations or absence of them. The two sides require separate attention. On the left side the scapula is essentially normal except for a much reduced humeral process, the coracoid is shorter than usual and has its ventral extremity faced more laterally than the normal, while the furcular tubercle of the coracoid is absolutely lacking and the humeral tubercle is rudimentary. The left half of the furcula is normal except for the absence of an articular enlargement at its dorsal extremity. A movable joint exists on the

left side between the scapula and the coracoid. The right shoulder girdle is decidedly more aberrant than the left, the scapula fails to narrow at its anterior extremity, faces more laterally than usual, bears no trace of a humeral process, and is completely fused with the coracoid along the entire dorsal margin of the latter bone. The right coracoid resembles the left in general form and the absence of a furcular tubercle, but differs from its mate in having no humeral tubercle and only a very rudimentary scapular tubercle. The right half of the furcula is like the left except for a decided median convexity, perhaps, like the asymmetry of the sternum, due to falls in early life.

The foramen triosseum, bounded by the antero-dorsal extremities of the scapula, coracoid, and furcula, is absent on the right side and decidedly reduced in caliber on the left side of the wingless skeleton. On both sides of the wingless bird the angle between the scapula and the coracoid is almost twice the normal, while the angle between the coracoid and the furcula has been correspondingly reduced, carrying the ventral extremity of the furcula almost against the anterior margin of the sternum.

Absolutely no trace of wing bones, nor indication of a humeral joint capsule, is present on either side of the skeleton of the wingless rooster.

CONCLUSIONS

It now remains to consider the cause and the significance of the already described abnormalities of this wingless rooster.

Two unpublished instances of wingless hens are known to us. Concerning one of these wingless hens we possess no details; the other was an incubator-hatched bird which was killed when only a few weeks old and lost to science.

It is well known to those who use incubators extensively that whenever, through some error of the regulating mechanism, the temperature rises a few degrees above the optimum, abnormalities result which in the majority of cases prevent the embryos from developing to the hatching stage. In view of this, and also of the evidence set forth below, we believe our wingless

rooster to have been produced by unusual temperature conditions in his environment, probably at the end of the first week of incubation.

The muscular anomalies fall into two groups: (1) Muscles which were present on the wingless bird but which differ from the normal in origin, insertion, or number of fibers; (2) muscles which were absent. A complete list of the muscles having unusual origins would include almost all of those present on this bird, but without more extensive knowledge of the normal limits of variation it is impossible to tell just how far abnormal these origins are, and furthermore the causes of such abnormalities must in most instances be far too complex for us to analyze them. The pectoralis muscles, however, are so evidently outside the normal limits of variation that attention should be called to them, and the partial explanation may in this case be hazarded that the reductions in origins are due to disuse, there being no wings present for them to move. The same is true of size of muscles, as of origins.

The abnormal insertions of muscles of the wingless rooster are of great interest and importance, and they can be collectively described as an inosculation between the fibers of the muscles arising along the dorsal side of the body, with normal insertions on the humerus, and the fibers of muscles, likewise with normal insertions on the humerus, but with origins on the ventral side of the body, the specific unions being between muscles of the same plane. This condition exactly coincides with what might be expected to occur in case the wings failed to develop while the rest of the body grew normally, for in the embryo the wing buds starting to grow out from the body wall carry with them the tissue destined to form their musculature.

The absent muscles would normally all have had their origins in the vicinity of the antero-dorsal angle of the shoulder girdle, where very evidently the focus of disturbance was located, and their insertions on the humerus, which is absent. What the immediate cause was of their failure to develop or of their subsequent atrophy, there is no evidence to show, but in the case of the deltoids and the biceps their place of origin is absent,

while the triceps origin may be represented by an anomalous tendon from the pectoralis minor.

The entire skeleton of the wingless rooster is heavier than any of our normal specimens of the same breed. Miss Lindsay ('85) states that in the chick, early in the sixth day of incubation, both cervical ribs are attached to the sternum at their ventral extremities while the scapula and coracoid are fused into a continuous cartilaginous plate. She further states that on the seventh day of incubation the cervical ribs have lost their connection with the sternum. The wingless rooster of the present paper has therefore on his right side the persistent embryonic condition of the sixth day of incubation as regards the second cervical rib and the relation between the coracoid and scapula. On his left side the sternal segment of the second cervical rib started normally to atrophy but never completed the process, while the coraco-scapular plate developed a normal joint. The fact of these abnormalities being normal for the six day embryo is our reason for believing that the disturbance which produced these abnormalities must have occurred at about that time. Why no traces of any wing bones are present it is impossible to say, but the complete absence of any capsule for a humeral joint goes to prove that they never started to develop.

In a word, all the evidence derived from a study of this wingless rooster, including the failure of extensive breeding experiments to produce any wingless offspring, indicates that his abnormalities were all instances of arrested development.

No extensive bibliography of the literature on avian anatomy accompanies this paper as such lists can be found in the works of either Gadow ('91) or Furbringer ('88).

The drawings used to illustrate this paper were, with the exception of those of the humerus, built up on photographs of skeletons; the parts desired being outlined in ink on the photographs, the latter then bleached with hypo and red prussiate of potash, and after they were dry the details put on in ink.

July, 1914

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Fig. 1 Photograph of the wingless rooster when about one year old.

Fig. 2 Normal left humerus showing topography of the bone and points of origin and insertion of muscles belonging to the shoulder region. Four views, from left to right, lateral, ventral, medial, and dorsal. *B.*, biceps brachii; *c.*, caput; *Cb.a.*, coraco-brachialis anterior; *Cb.p.*, coraco-brachialis posterior; *c.i.*, inferior crista; *c.s.*, superior crista; *D.mj.*, deltoid major; *D.mn.*, deltoid minor; *f.p.*, pneumatic foramen; *L.d.*, latissimus dorsi; *P.mj.*, pectoralis major; *P.mn.*, pectoralis minor; *Sh.a.*, scapuli-humeralis anterior; *Sh.p.*, scapuli-humeralis posterior; *S.s.*, subcoraco-scapulares; *T.*, triceps cubiti; *t.i.*, inferior tubercle; *t.s.*, superior tubercle.

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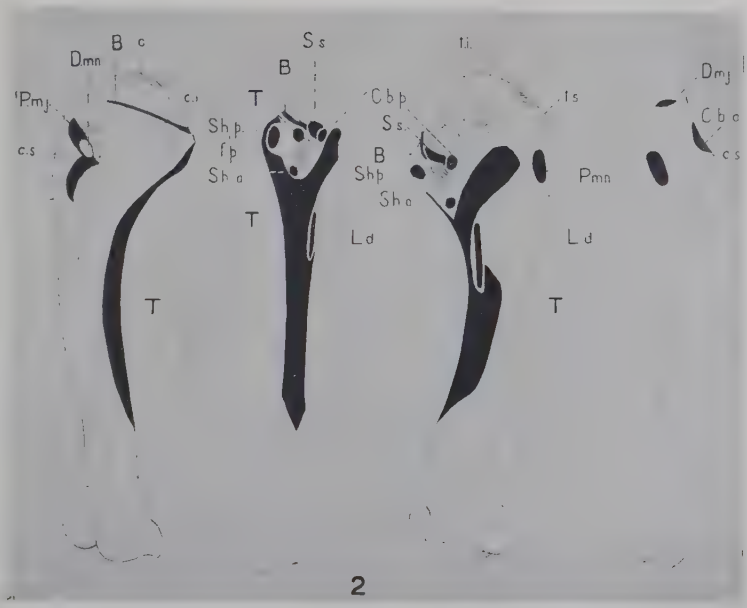
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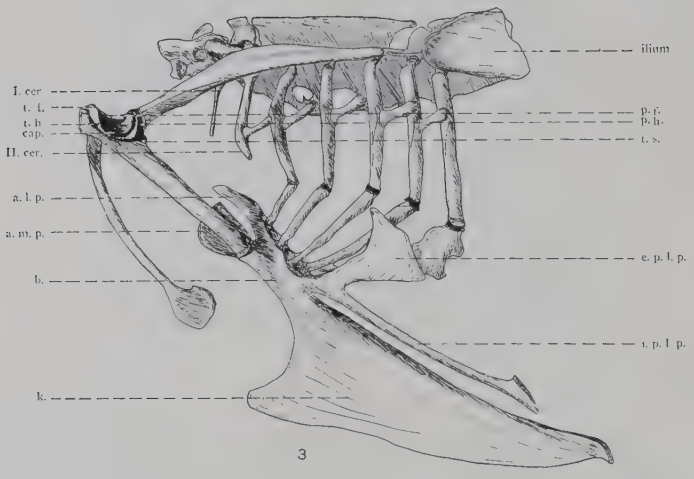
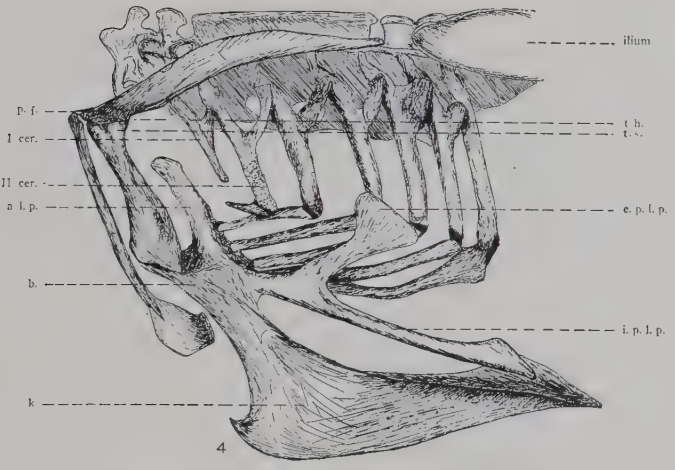


Fig. 3 Thoracic region of normal skeleton viewed from left side. *a.l.p.*, *a.m.p.*, *b.*, anterior lateral and median processes, and body of sternum; *cap.*, capsule of humeral joint; *e.p.l.p.*, *i.p.l.p.*,*k.*, external and internal posterior lateral processes, and keel of sternum; *p.f.*, *p.h.*, furcular and humeral processes of scapula; *t.f.*, *t.h.*, *t.s.*, furcular, humeral, and scapular tubercles of coracoid, *I. cer.*, *II. cer.*, first and second cervical ribs.

Fig. 4 Thoracic region of wingless skeleton, viewed from left side. *a.l.p.*, *b.*, *e.p.l.p.*, *i.p.l.p.*, *k.*, anterior lateral process, body, external posterior lateral process, internal posterior lateral process, and keel of sternum; *p.f.*, furcular process of scapula; *t.h.*, *t.s.*, humeral and scapular tubercles of coracoid; *I. cer.*, *II. cer.*, first and second cervical ribs.

Fig. 5 Thoracic region of wingless skeleton, viewed from right side. *a.l.p.*, *b.*, *e.p.l.p.*, *i.p.l.p.*, *k.*, anterior lateral process, body, external posterior lateral process, internal posterior lateral process, and keel of sternum; *p.f.*, furcular process of scapula; *t.s.*, scapular tubercle of coracoid; *I. cer.*, *II. cer.*, first and second cervical ribs.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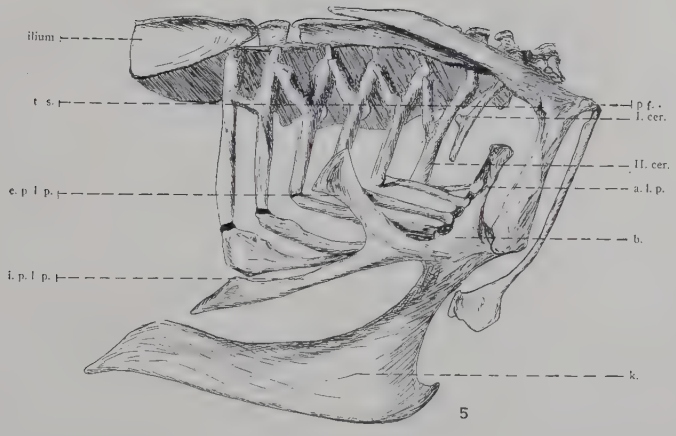
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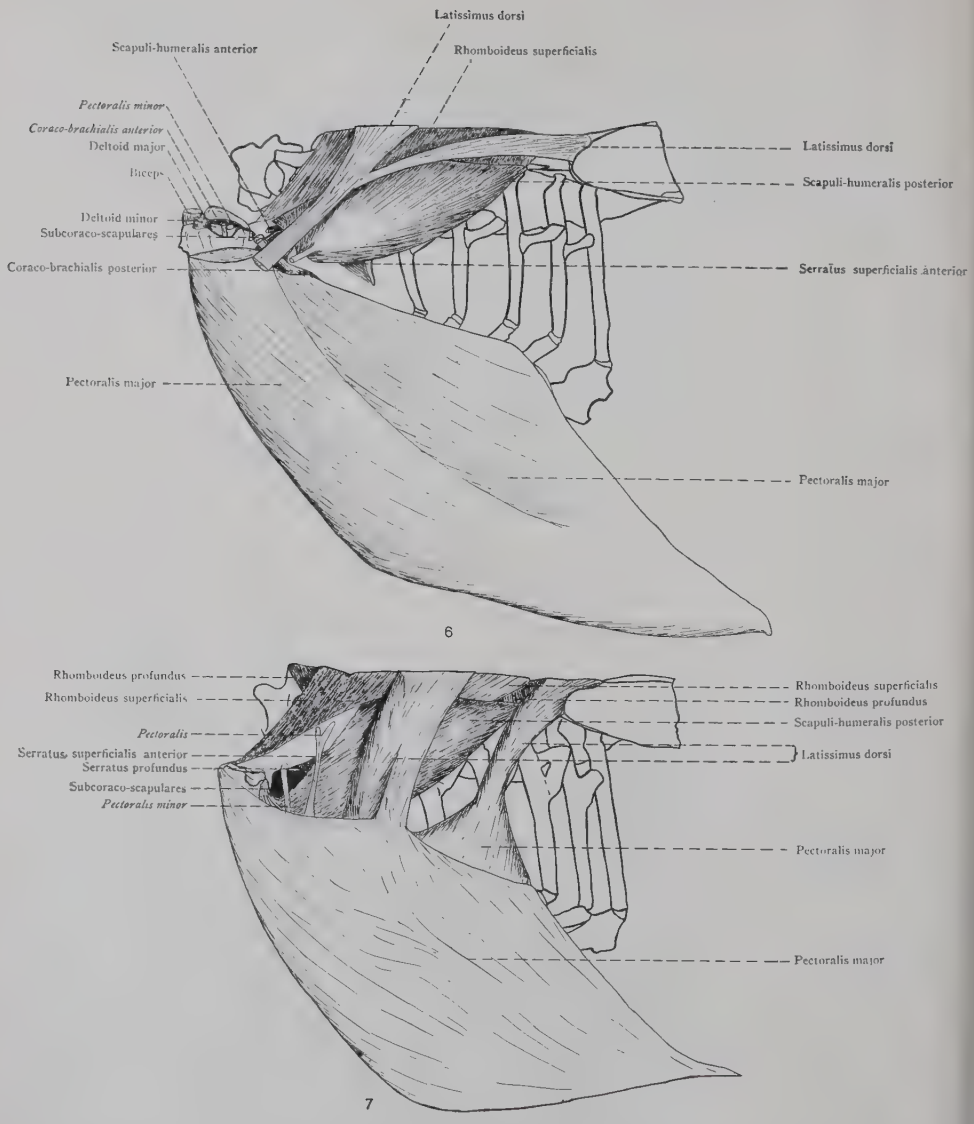
5

SHOULDER REGION OF A WINGLESS FOWL

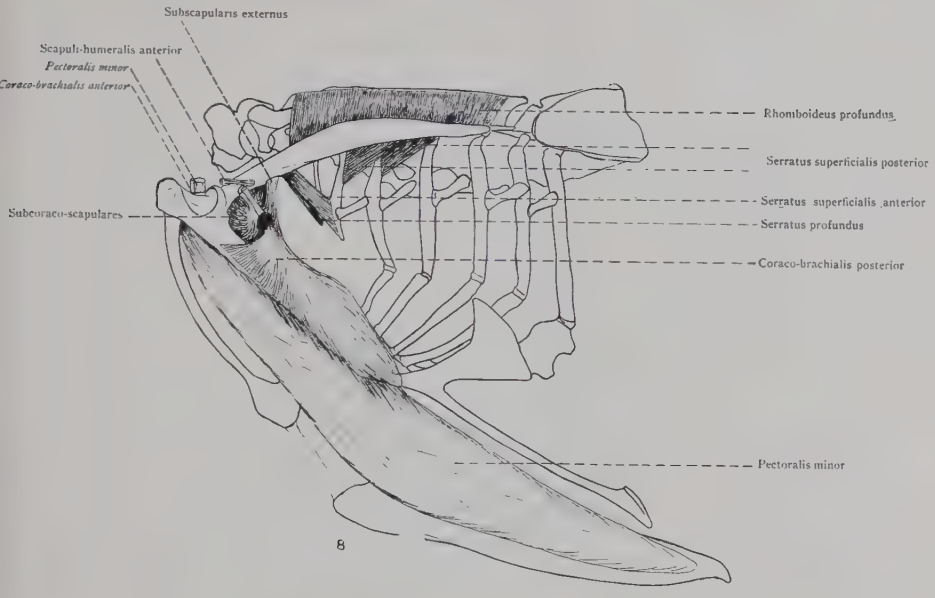
W. B. KIRKHAM AND H. W. HAGGARD

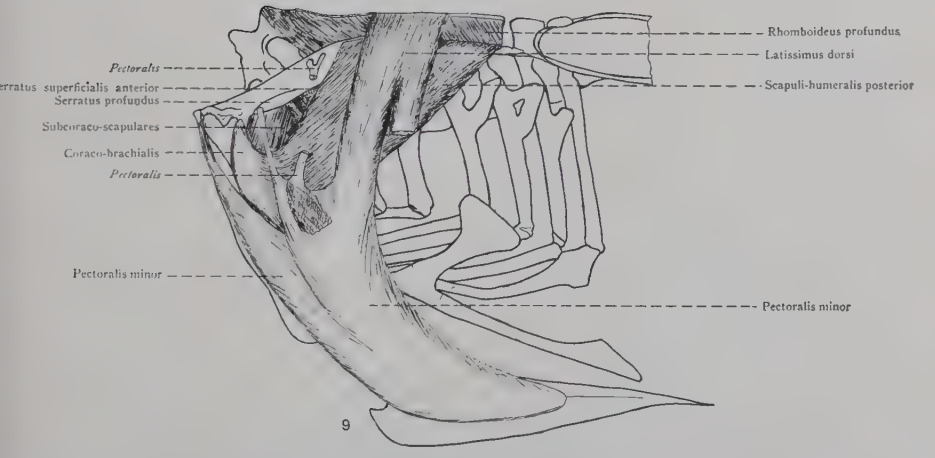


EXPLANATION OF FIGURES

6 Diagram of superficial muscles of shoulder region; normal rooster. Insertions in italics.

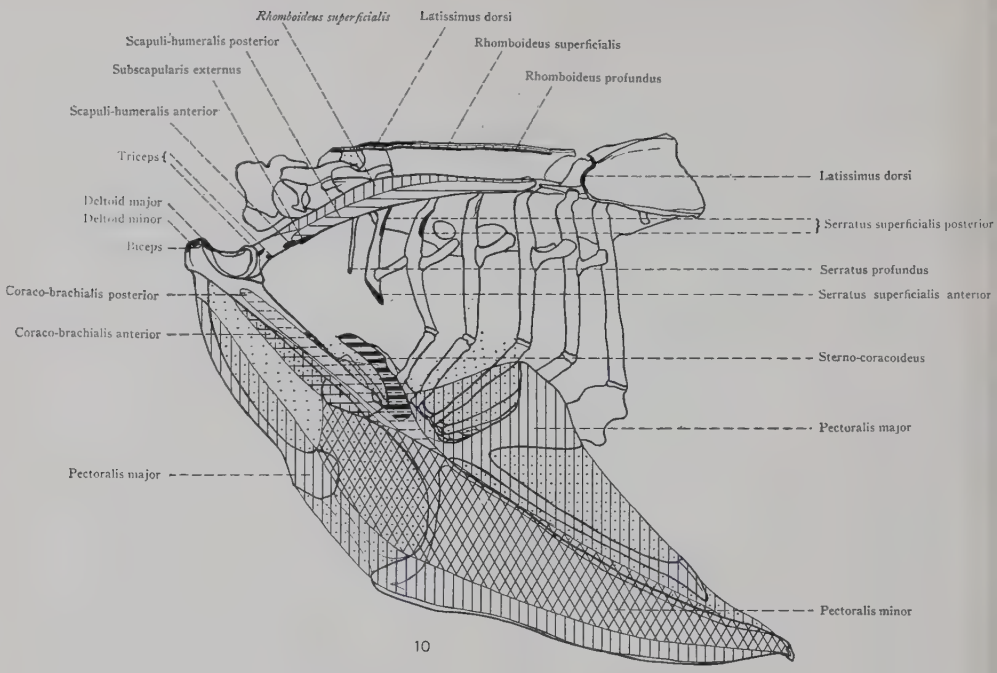
7 Same as above; wingless rooster.

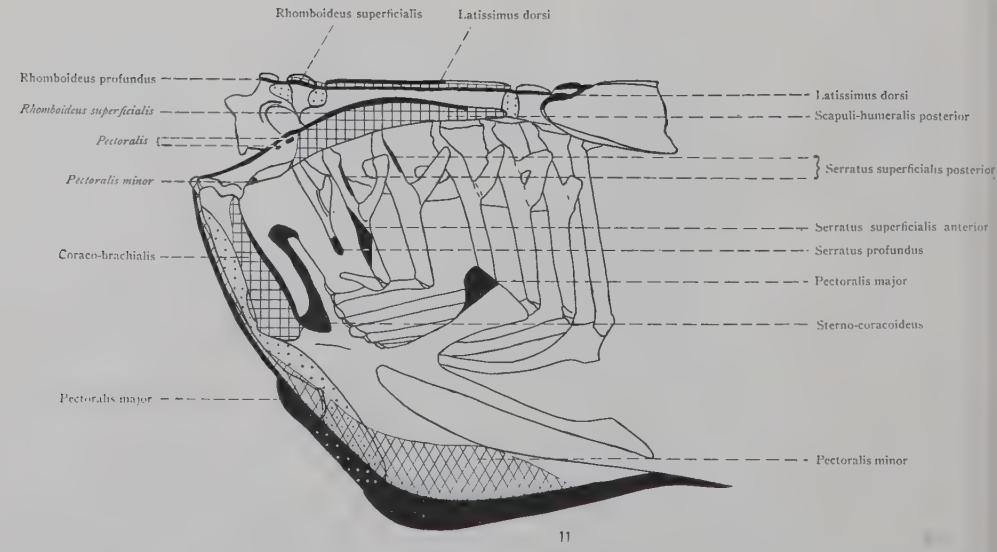




EXPLANATION OF FIGURES

8 Diagram of deep muscles of shoulder region; normal rooster. Insertions in italics.
9 Same as above; wingless rooster.





EXPLANATION OF FIGURES

10 Diagram of origins and insertions of superficial and deep muscles of shoulder region; normal rooster. Insertions in italics.

11 Same as above; wingless rooster.

REPORT OF THE ANOMALIES IN A SUBJECT WITH A SUPERNUMERARY LUMBAR VERTEBRA

H. RYERSON DECKER

From the Anatomical Laboratories, School of Medicine, University of Pittsburgh

SIX FIGURES

The specimen here reported was obtained in the dissecting room of the School of Medicine, University of Pittsburgh. The body was that of an adult white male.

In the vertebral column there are thirty-three vertebrae arranged as follows: seven cervical, twelve thoracic, six lumbar, four sacral and four coccygeal. In the cervical region there are no anomalies. In the thoracic region there is a right scoliosis with lordotic tendency, corresponding to the bodies of the fourth to seventh vertebrae and the spines of the fourth to sixth vertebrae. The ribs on the right side are so bent as to narrow and deepen the costo-vertebral groove. The twelve ribs are in normal position but the lower ribs, especially the twelfth pair, are longer than usual, measurimg 18 cm. and reaching bilaterally to within 4 cm. of the iliac crest.

There are six lumbar vertebrae. The first vertebra carries a lumbar rib bilaterally. This is short, 2.5 cm. long by 1.2 cm. wide, and articulates by a facet on the upper half of the lateral aspect of the body of the vertebra, as well as by a facet on the transverse process. It resembles in every way except for its articulations the transverse process or costal element of the other lumbar vertebrae. The vertebra itself resembles morphologically a lumbar rather than a thoracic vertebra. It has the quadrate horizontal spine, the larger body, the well-defined mammillary process. Of the other lumbar vertebrae, the sixth only is anomalous. It presents a spine rather narrow and clubbed at the end, which is deflected 0.7 cm. to the left of the median line.

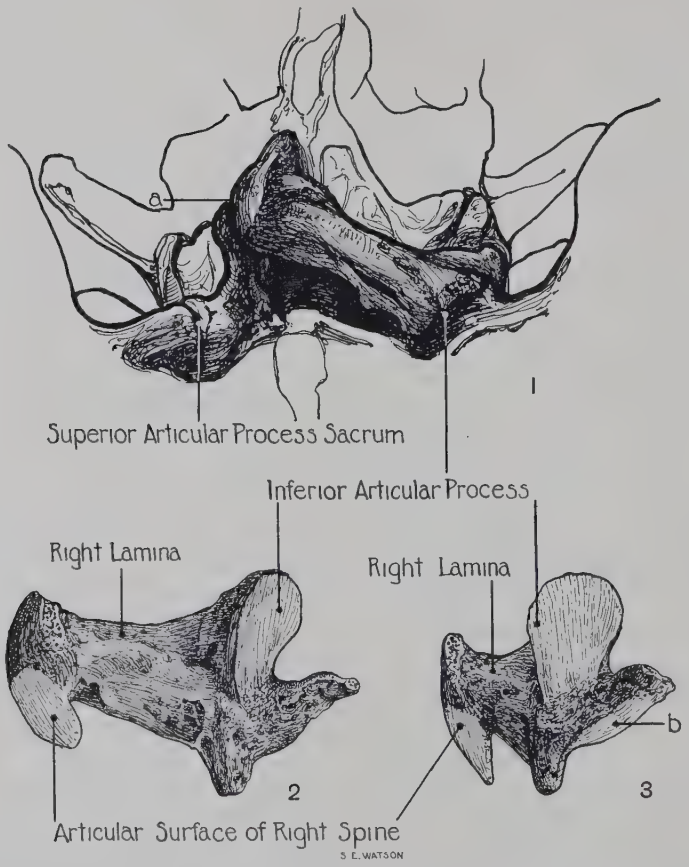


Fig. 1 Diagram of VIth lumbar vertebra from behind, showing cleft in spine at *a*.

Fig. 2 Drawing of detachable portion of neural arch of VIth lumbar vertebra from in front.

Fig. 3 Drawing of detachable portion ot neural arch of the VIth lumbar vertebra, lateral aspect. Articular surface in pedicle shown at *b*.

The spine itself is split into two unequal portions with an articular surface between. The left portion is shorter, 1.2 cm. long, more or less pointed, and is attached to a lamina 1.5 cm. broad, and with the lamina is directed backward and outward so as to be slightly concave laterally. The right portion embraces most

of the spine, is club-shaped, and is attached to a lamina 1.6 cm. broad, which is directed almost horizontally outward (fig. 1). Another defect in the neural arch occurs in the right pedicle just behind and below the superior articular process, where there is a narrow irregular articulation, 2.3 cm. by 0.6 cm. long, looking upward and slightly forward. The separation of the pedicle is not complete, however, for below this joint, between it and the inferior articular process there is definite bony continuity. In other respects the vertebra is normal (figs. 2–4).

The sacrum presents only four vertebrae, and the coccyx four. The first coccygeal vertebra is ankylosed to the last sacral. The anomalies of this vertebral column then, summarized, are the presence of an extra lumbar vertebra, the absence of one sacral segment, the addition of a lumbar rib, a thoracic scoliosis, and an ununited neural arch in the sixth vertebra.

The intervertebral foramina correspond to the number of segments in each region. Thus there are six in the lumbar region and four in the sacral region. Through the foramen between the sacrum and the sixth lumbar vertebra, the spinal branch of the iliolumbar artery passes in, as it does normally, between the fifth vertebra and sacrum, while an extra nerve which may be designated as the sixth lumbar nerve, passes out to join the fifth lumbar and a communication from the fourth lumbar and first sacral to form the sacral plexus (figs. 5–6). Through the foramen between the fifth and sixth vertebra passes a spinal branch of the fifth lumbar artery, which in turn is of large size and given off in normal fashion from the middle sacral artery. Through the first four foramina lumbar branches of the abdominal aorta enter (fig. 5). There are no muscular or ligamentous anomalies.

Special mention is made of the arterial and nervous arrangement because in the usual description of anomalous vertebral columns found in the literature no record is made of the disposition of the soft parts.

From this description it will be noted that the specimen presents both numerical and morphological variations. Numerical variations in the experience of all investigators are most frequent

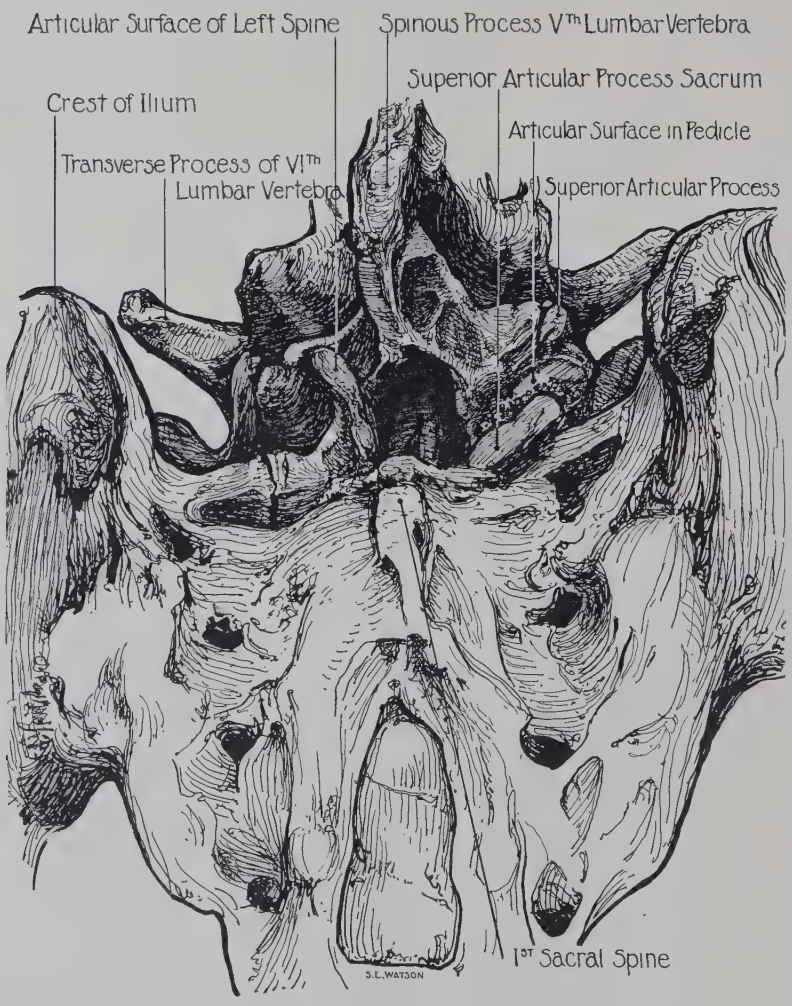


Fig. 4 Drawing of VIth lumbar vertebra with detachable portion of neural arch removed.

in the coccygeal region, since here a certain number of original embryonal segments fail to persist. In the adult there may be as few as three, the others having been lost or fused. Steinbach

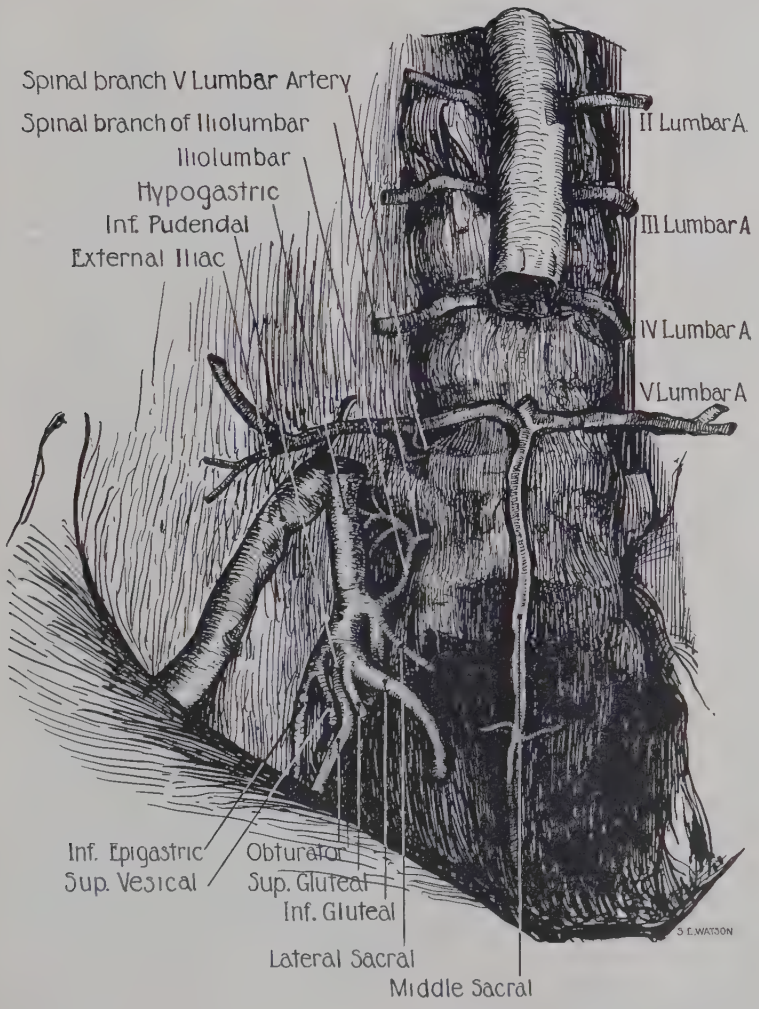


Fig. 5 Diagram of arterial distribution in region of VIth lumbar vertebra.

('89) believes that five are normal for the male and four for the female, while Bardeen ('04) thinks that normally not more than four sacral vertebrae persist. Variations are less frequent in the

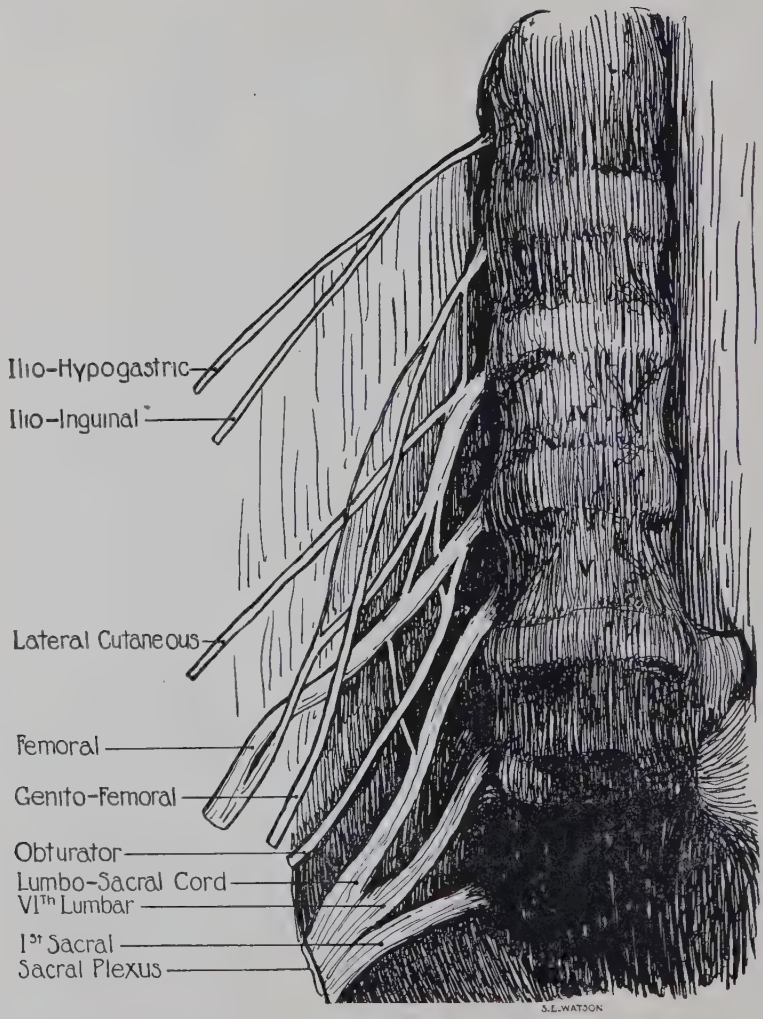


Fig. 6 Diagram of lumbosacral plexus in region of VIth lumbar vertebra.

sacral region, and the frequency diminishes as we ascend the vertebral column, so that in the cervical region numerical variation is rare.

In the presacral region there are normally twenty-four vertebrae, numerical variations here arranging themselves into two groups; first, where the total number of segments is either increased or diminished without compensation from another region; secondly, where the total number of presacral vertebrae is twenty-four but increase or diminution in one region occurs at the expense of an adjacent region, as in the specimen here described, where a sacral deficiency is compensated for in the lumbar region. Variation of this type seems to be concomitant with the development and attachment of the costal element. Thus in the lumbosacral region the last lumbar vertebra may be sacralized by fusion of its costal element in the lateral mass, or the first sacral vertebra may be set free and lumbalized because of lack of fusion of its costal element.

Numerical variations have been studied by a number of investigators, notably Bianchi, Steinbach, Paterson, Ancel and Sencert, Topinard, Dwight, Rosenberg and Bardeen. Bardeen ('04) after a study of reports of 1059 specimens including 75 of his own, found that numerical variations occur in about 16 per cent of vertebral columns of which 7.3 per cent have compensated variations and 8.7 per cent uncompensated, equally divided between an increase and decrease of segments.

Morphological variations are comparatively infrequent, although there are no actual figures. Anomalies of form may exist in any part of a vertebra and may be unilateral or bilateral. The common types are defects in the neural arch, defects in the body, deviation in the normal alignment of parts, and synostoses. Variations in the size of spinous processes, laminae, articular processes, bodies, from hypertrophy to dwarfing are not uncommon. When morphological defects occur they are usually in the lumbar region.

Defects in the neural arch may occur at any place, but commonly are seen in the pedicle between the superior and inferior articular processes, so that a segment consisting of spinous process and laminae may be lifted away when the soft parts are divided. They may be, as in the specimen here described, asym-

metrical and incomplete. Complete absence of part of the neural arch as occurs in spina bifida is not uncommon. Anomalies of this type are easily explained by the failure of centers of ossification to develop fully and unite.

When one comes to account for numerical variations, explanations are not so easy to give, leading to the development of a number of theories which are well discussed by Bardeen ('04) and by Testut ('11). It is not within the scope of this report to discuss these further than to state that numerical variation can be reasonably explained on the simple basis of errors in segmentation.

From a clinical standpoint it would seem that numerical variation is not an important factor. There is no ground for believing that one vertebra more or less regionally or otherwise is of disadvantage to an individual. Morphological anomalies, on the other hand, may easily be the cause of or be associated with definite disturbance in body function. Defects in the neural arch or defects in normal proportions of a vertebra may tend to render that vertebra more unstable, its articulations more insecure, and to permit abnormal motion between the bodies or adjacent articular processes. When such a vertebra is subjected to acute or to long-continued force, muscular strains, joint sprains, spinal curvature, and even dislocation may happen. Much backache may be due to vertebral defect. If the last lumbar vertebra be the one affected, instability may be given to the lumbo-sacral articulation, and a true projection forward of the promontory of the sacrum may occur to such an extent as to interfere with normal parturition. Lack of fusion in the neural arches in spina bifida is of course a distinct clinical entity, as is often the presence of a cervical rib. Just what was the exact clinical aspect of the case here reported, is not on record.

I desire to acknowledge many suggestions received from Professor Sheldon in connection with the preparation of this article.

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INCREASE IN PRICE OF JOURNALS

In order to extend and improve the journals published by The Wistar Institute, a Finance Committee, consisting of editors representing each journal, was appointed on December 30th, 1913, to consider the methods of accomplishing this object. The sudden outbreak of European misfortunes interfered seriously with the plans of this committee. It was finally decided, at a meeting held December 28th, 1914, in St. Louis, Mo., that for the present an increase in the price of these periodicals would not be unfavorably received, and that this increase would meet the needs of the journals until some more favorable provision could be made.

This increase brings the price of these journals up to an amount more nearly equal to the cost of similar European publications and is in no sense an excessive charge.

The journals affected are as follows:

THE AMERICAN JOURNAL OF ANATOMY, beginning with Vol. 18, price per volume, $7.50; foreign, $8.00.

THE ANATOMICAL RECORD, beginning with Vol. 9, price per volume, $5.00; foreign, $5.50.

THE JOURNAL OF COMPARATIVE NEUROLOGY, beginning with Vol. 25, price per volume, $7.50; foreign, $8.00.

THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY

36th Street and Woodland Avenue

Philadelphia, Pa.

ON THE ANLAGE OF THE BULBO-URETHRAL (COWPER'S) AND MAJOR VESTIBULAR (BARTHOLIN'S) GLANDS IN THE HUMAN EMBRYO

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FOUR FIGURES

The first observations on the development of Bartholin's glands were published in 1840 by Tiedemann, who saw them in embryos of five, six and seven months. Huguier found the glands in an embryo of four and a half months. Hoffman determined that the anlage of Cowper's glands first appeared in the tenth to eleventh week, on both sides of the urogenital opening, near the anlage of the penis. Toldt recorded that both Cowper's and Bartholin's glands originated as outpouchings of the urogenital sinus. Debierre saw Cowper's glands in a seven-months' fetus, and declared its anlage to be an outpocketing of the epithelium of the urethra. Beigel observed Bartholin's glands in a six-months' fetus, and Swiecicki in one of 99 mm. Van Ackeren states that he found Bartholin's glands in an embryo at the end of the fourth month, and records that he observed the gland duct as entering the lowest portion of the urogenital sinus. He further states that the blind end of each duct bore five epithelial twigs, separated from each other by connective tissue. Cadiat indicated the anlage of Cowper's glands in his figure of a 3.5 cm. embryo; the validity of his interpretation, however, is questioned by v. Müller. Tourneaux found in a 4.4 cm. embryo the anlagen of Bartholin's glands in the form of epithelial buds having a length of 120 μ.

The observations of Vitalis Müller deserve fuller consideration. An embryo of 27 mm. length did not show any trace of Bartholin's glands. The next embryo in his series was one of 6.5 cm. length, though one of 8 cm. length showed an earlier stage of the gland anlage. In the latter embryo, the two epithelial buds were respectively 133 μ and 166 μ in length, and without lumen. A male embryo of 6.75 cm. showed buds of 300 μ and 100 μ, with a lumen in the longer bud. In a female embryo of 6.5 cm. length, he observed the left bud as having a length of 400 μ and presenting two end branches, and the right bud as having a length of 750 μ with three end branches, both buds showing lumina. From these and other embryos, Müller concluded that the first appearance of these glands is irregular as to time, and may take place in embryos of from 4 to 8 cm. in length. This author states, in substance, that the

anlagen of Cowper's and Bartholin's glands arise as solid buds from thickenings of the epithelium of the urogenital sinus. The solid anlagen later acquire a lumen, the ends extending as solid sprouts, the beginnings of division. Between the distal buds there is found a cellular mesenchyme. He further notes that in cross-sections of the urogenital sinus, this has the form of a five-rayed star, the gland anlagen always arising from the two lower or ventral rays; in younger embryos growing laterally, in embryos of 10 to 11 cm., latero-dorsally. Müller also studied ox embryos of 6 cm. length. In these he observed that the urogenital canal presents in transverse section the form of a cross with side arms running to a point. On the crest of these side arms, as seen in cross-section, he found the anlagen of Cowper's glands as two solid buds of 100 μ to 150 μ in length.

Nagel observed the anlagen of Cowper's glands in a 4 cm. embryo, these appearing as solid tube-like epithelial buds on the sides of the urogenital sinus, somewhat above its external opening. The epithelium of the gland buds he found to be of a high cubic variety. He found end branches in the gland anlagen of embryos of 5 to 6 cm., rump length. In older embryos, the hollowed-out ducts of the gland anlagen were lined by a low cubic epithelium, as in the canalis urogenitalis; while the branches had a high, almost cylindrical epithelium, as in the early stages of the anlagen.

Robert Mayer, in his account of the development of the glands of the vagina and the vulva, gives consideration to the Bartholin's glands as observed in embryos of five months and older. He notes that in the vestibule of the female embryo, longitudinal folds are formed at an early stage; in embryos up to about five months old, these folds appear, in cross-sections of the vestibule, arranged in the form of a star having five principal rays on each side. As described by him, the first pair of rays runs in front from the urethral opening parallel to the clitoris. The second pair of rays passes on both sides of the papilla urethralis, passing diagonally backward from what has been termed the 'sulcus paraurethralis.' This pair of folds, which early bears relatively large glandlike recesses, remains backward in growth, and is poorly developed in the newborn, though still recognizable. The third pair of folds or rays—which as seen in cross-section of the urogenital sinus, forms the middle of the star—is characterized by the ducts of Bartholin's glands. The fourth pair, situated just behind the third pair and running parallel to the ducts of Bartholin's glands, have a direction which is obliquely backward, and support, in the newborn, glandular anlagen which are similar to those of Bartholin's glands, except that shorter tubules are found. The fifth pair of folds is situated in the fossa navicularis, beside the midline, having a direction which is upward rather than backward. Mayer points out that it is along these five rays or folds that the glands of the vulva first develop, and it is here that they form in the greatest numbers.

Keibel's observations on Echidna embryos have influenced the more recent investigators who have considered the anlage of Cowper's gland

in Homo. Keibel found in his echidna embryo 45 a, length 7.7 mm. a thickening of the ectodermal epithelium to the right and left of the midline which, to use his own words, "may perhaps be ascribed to the anlage of Cowper's gland." This region is stated to be at the cranial end of the just forming ectodermal cloaca. In his Echidna embryo 46, the Cowper's gland anlage is present as an elongated solid bud arising from the ectoderm at the base of the penis; that is, from the craniolateral wall of the ectodermal cloaca (see Keibel's text figures 53 a and 53 b, and plate figures 17, 19 and 20). The upper end of the gland anlage is invested by a muscle complex that is continuous with the muscle of the skin.

Van der Broek established a similar origin for Cowper's glands in the embryos of Marsupia. In a Halmaturus embryo of 17.5 mm., he observed what he took to be the anlage of Cowper's glands, arising from the ectoderm of the ectodäum (Keibel's ectodermal cloaca) on both sides of the urethral plate (Phallusleiste). In later stages of the embryos of Halmaturus and other Marsupia, he found Cowper's glands as solid epithelial buds, arising from the urogenital sinus at the boundary between the ectoderm and the entoderm.

Lichtenburg, in a comprehensive investigation on the development and structure of the urogenital canal in man, in the course of which he made free use of reconstruction methods, accepts without verification the account given by Keibel and Van der Broek of the ectodermal origin of Cowper's glands as observed in the Monotremata and Marsupia, and makes their findings applicable to man. In a 48 mm. human embryo, the youngest stage described by him, Lichtenburg finds the anlagen of Cowper's glands "at the typical place on the dorsal wall of the urogenital sinus." It appeared to him, to quote further, "as if the tubules were not naked, but that a kind of compressed embryonic connective tissue formed a capsule around them." In a 65 mm. embryo, the gland buds were found to be unbranched, though both buds possessed a lumen; small side buds indicated future branching. Lichtenburg's figure (p. 143) shows the gland buds lying side-by-side near the mid-line and dorsal to the urogenital sinus. In an embryo of 68 mm. length, terminal branching of the gland buds was evident, while one of 70 mm. length showed an accessory Cowper's gland.

Felix, in his account of the anlage and development of the urogenital organs as given in Keibel and Mall's "Human Embryology," makes the following observations concerning Cowper's glands: "They arise as paired solid epithelial buds from the pars pelvina of the urogenital sinus" . . . "and are therefore of entodermal origin. The solid epithelial buds grow upward almost parallel to the urogenital sinus, and lie from the beginning in the compact mesenchyme which is the anlage of the corpus cavernosum urethrae. The glands grow through this mantle, and only when they have reached the looser mesenchyme between the rectum and the sinus are they able to enlarge." Felix observed the anlagen of Bartholin's glands in an embryo of 36 mm.;

the first evidence of branching in the gland-buds of Bartholin's glands were observed in an embryo of 80 mm. length.

Broman states that Bartholin's glands are first evident in female embryos of the third month, 4 to 8 cm. long, as paired outgrowths from the epithelium of the urogenital sinus, basing his statement on the observations of Vitalis Müller. Cowper's glands arise as buds from the entodermal urogenital sinus epithelium, in 4 to 5 cm. embryos. His figure 397 reproduces a model of the urogenital sinus and Cowper's glands of a male embryo of 6 cm. head-breech length.

This brief review of the literature may serve to show that while the embryology of Cowper's and Bartholin's glands has received consideration by numerous investigators, there is as yet no unanimity as to the period when their anlagen in the human embryo may first be recognized, nor has the region of their anlagen been definitely determined, and, with the exception of the figure of Broman, there exist no comprehensive figures showing their relation to the urogenital sinus, mesonephric ducts, and Müllerian ducts. At the suggestion of Dr. Huber, models of the epithelial portions of the genital tubercle, urogenital sinus to base of bladder, ureters, mesonephric and Müllerian ducts, and rectum of human embryos, both male and female, at the critical period of their development, were undertaken. The models thus obtained, while in part duplicating certain of the Keibel models, seem worthy of reproduction, in that the anlagen of Cowper's and Bartholin's glands are portrayed in their relation to other structures. The question of the ectodermal or entodermal origin of these glands is not considered, as a solution of this question is not to be obtained from embryos of the age of those used in this investigation. For this, much younger stages showing early cloacal development would be necessary. The problem confines itself to a study of the anlage of Cowper's and Bartholin's glands in their relation to the urogenital sinus and associated structures, as shown in a series of reconstructions of critical stages.

The human embryos from Dr. Huber's collection (table 1) were placed at my disposal, the measurements referring to crown-breech length, as obtained in fixed material (formalin fixation). With the exception of Embryo 48, in which there is evidence of

maceration, the embryos are all well preserved. The series are double stained in hematoxylin and congo red. Reconstructions were made from the first four of the embryos listed; the other three were studied without being modelled. The drawings for the reconstructions were made with the aid of an Edinger projection apparatus, at a magnification of 100 diameters. In all cases, the epithelium alone was reconstructed. These models, which form the basis of the study, are figured as seen from the left side. The figures were made by photographing the models and using the negative for lantern slide projection, accurate outlines being thus obtained. By placing the drawing paper at the right distance from the lantern, it was possible to give a definite magnification to the figures. My own account consists mainly of a description of the models made.

TABLE 1

No. 47	32 mm.	female	sagittal	15 μ sections
No. 15	30 mm.	male	sagittal	10 μ sections
No. 18	45 mm.	female	sagittal	10 μ sections
No. 23	60 mm.	female	sagittal	10 μ sections
No. 39	39 mm.	male	sagittal	10 μ sections
No. 49	47 mm.	female	sagittal	15 μ sections
No. 48	48 mm.	female	sagittal	20 μ sections

The model made from Embryo 47 is shown in figure 1. This embryo was secured from the service of Professor Peterson, from a case of hysterectomy for large fibroma; it was fixed while still warm, and is in an excellent state of preservation. In the model are reproduced the lower part of the much distended bladder, the mesonephric and Müllerian ducts and ureters. These structures present the typical, normal arrangement, with as yet no degeneration of the mesonephric ducts. Externally, the phallus shows, between its distal and middle thirds, a shallow coronal groove, the sulcus coronarius glandis. A small depression marks the anal pit, and a similar one the ostium urogenitalis, a shallow groove connecting the two depressions. The anal membrane is still unbroken.

Each side of the wall of the urogenital sinus presents three epithelial ridges or folds. These may be designated as the upper,

ABBREVIATIONS

bl., bladder
b.ur.gl., bulbo-urethral glands (Cowper's glands)
l.f.ur.si., lateral folds of the urogenital sinus
m.vs.gl., major vestibular glands (Bartholin's glands)
m.n.d., mesonephric duct
M.d., Müllerian ducts
utero-vaginal canal
pa.u.gl., paraurethral glands (Skene)
rct., rectum
s.cor., sulcus coronarius
s.ny.l., sulcus nympho-labialis
u., ureter
ur.pl., urethral plate

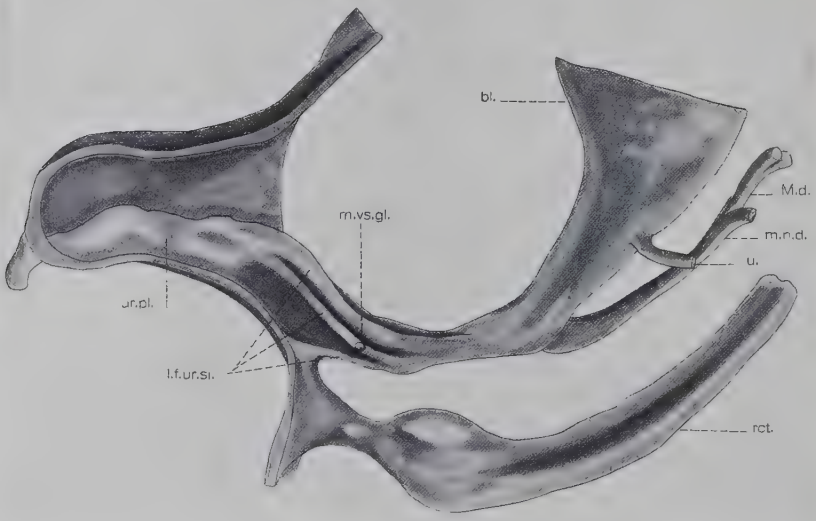

Fig. 1 Model of epithelial portion of urogenital system of human Embryo 47 (Huber collection); female, 32 mm. crown-breech length. × 20.

middle, and lower lateral folds of the urogenital sinus. These folds begin in a region which is 0.7 mm. distal or caudal to the entrance of the mesonephric ducts into the urogenital sinus, and spread out radially. Of these folds, the upper lateral folds are the most prominent. When the model is viewed from above, it may be seen that they enclose a relatively deep fossa before blending in the sagittal plane to form the uppermost portion of the urethral plate. The middle lateral folds, shorter than the

upper ones, run nearly parallel to them, and are separated from the upper folds by relatively deep, narrow grooves. In their proximal portion, each middle fold presents an elevation of about 75 μ; distally or caudally, each middle fold slopes downward, becoming broader and lower, and is ultimately lost in the urethral plate. The lower lateral folds taken together form a thickened ridge along the bottom of the urogenital sinus, blending distally with the surface epithelium. They are the smallest of the three folds, both in length and elevation. That portion of the urethral plate found in the angle between the middle and the lower folds is relatively thin. Of the three sets of lateral folds observed in this embryo, only in the middle ones can a lumen or extension of the cavity of the urogenital sinus be at all clearly traced, and this as a narrow slit having a depth of about 20 to 30 μ.

On the left side of the model, as shown in figure 1, the middle lateral fold presents, near its cephalic end, a small projecting bud of epithelium, which passed through only one of the sections, having a thickness of 15 μ. The relative position of this epithelial bud is shown in this figure at *m.vs.gl.* Looking at the model from below, it may be observed that about 0.3 mm. from the cephalic end of the middle lateral fold, there is evident an abrupt rise or shoulder, and that the epithelial bud above referred to, caps this shoulder. From the older stages modelled, it is evident that this epithelial bud may be regarded as the anlage of Bartholin's gland. A similar bud is as yet lacking on the other, the right side of the urogenital sinus, though three lateral folds, similar in extent and arrangement to those figured for the left side may be seen in the reconstruction. The cells of the Bartholin's gland anlage of the left side, like those of the lateral folds and the wall of the urogenital sinus, may be characterized as of the cuboidal variety and stratified. The short epithelial bud is surrounded by a membrana propria, the surrounding mesenchymal cells having in the immediate vicinity a concentric arrangement.

The model made from Embryo 15 is shown from the left side in figure 2. This is a male embryo having a crown-breech length of 30 mm., and shows a slightly older stage of development than the female embryo, the model of which is shown in figure 1.

The anal membrane is perforated, and the anal pit is a distinct fossa. The perineum has a length of only 0.15 mm. The cephalic ends of the Müllerian ducts present evidence of beginning degeneration.

The three lateral folds of the urogenital sinus present essentially the same relative positions as those described in connection with the model shown in figure 1. By reason of the thickening

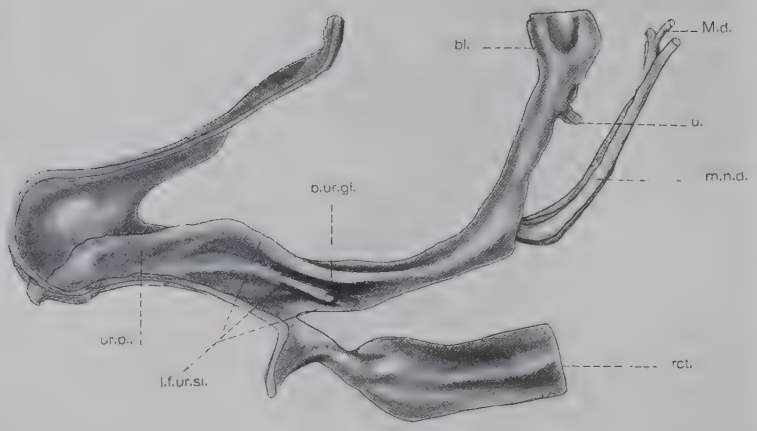

Fig. 2 Model of epithelial portion of urogenital system of human Embryo 15 (Huber collection); male, 30 mm. crown-breech length. × 20.

of the epithelial plate in the region between the middle and lower lateral folds, the lower folds are less conspicuous than in the preceding model. The middle fold is also somewhat shorter than in Embryo 47 (fig. 1). The anlage of Cowper's gland, present on both sides of the urogenital sinus, is observed in essentially the same relative position as given for the anlage of Bartholin's glands, namely, in the middle fold, capping an abrupt shoulder seen on this fold near its cephalic end, about 1 mm. below the

entrance of the mesonephric ducts into the urogenital sinus. The bud of the left side is shown in figure 2 at *b.ur.gl.* The gland anlagen are in the form of solid epithelial buds, composed of cells of a cuboidal form; the left bud having a length of 50 μ, the right bud a length of 60 μ. Both buds project laterally into a dense mesenchyme with a direction which is perpendicular to the long axis of the middle lateral folds. The gland anlagen are surrounded by a membrana propria, the surrounding mesenchymal cells having a concentric arrangement.

The shape of the sinus lumen for the region of the lateral folds differs from that described for Embryo 47. In Embryo 15 (fig. 2) the pars phallica sinus urogenitalis (Felix) has been extended by central desquamation of the cells of the urethral plate, the sinus lumen having invaded the upper lateral folds and that portion of the urethral plate found between the middle and the lower folds.

Embryo 39, male, crown-breech length 39 mm., was studied with reference to the urogenital sinus region, but not modelled. The lateral folds of the urogenital sinus were determined, the lower lateral folds being, however, quite inconspicuous. The anlagen of Cowper's glands were found near the cephalic ends of the middle lateral folds, as solid epithelial buds with as yet no peripheral branching. The bud on the right side passed through five 10 μ sections; that on the left, through nine 10 μ sections.

Embryo 18, from which the model shown in figure 3 was made, is a female embryo having a crown-breech length of 45 mm. In this embryo the mesonephric ducts present marked evidences of degeneration. When compared with Embryo 47, the general advance in the development of the urogenital structures may be noted. The phallus (clitoris) and the perineum are relatively shorter. A well marked sulcus coronarius glandis is present; a shallow groove, the urethral groove, extends to it from the ostium urogenitalis. Laterad, the sulcus nympho-labialis separates the phallus from the genital swelling. The ostium urogenitalis has increased in size, both in length and in width. The pars phallica sinus urogenitalis has developed to such an extent that it now

forms the widest part of the urogenital sinus caudal to the junction of the Müllerian duct with the urogenital sinus.

The model made from this embryo is shown from the left side in figure 3. The three lateral folds of the urogenital sinus are evident, and present some points of difference when compared with the three lateral folds as modelled from male Embryo 15.

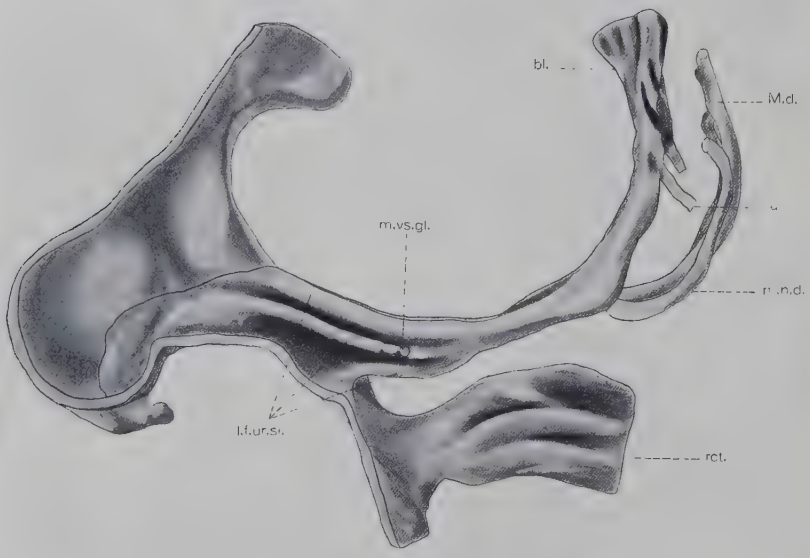

Fig. 3 Model of epithelial portion of urogenital system of human Embryo 18 (Huber collection); female, 45 mm. crown-breech length. × 15.

Only the upper lateral folds have not materially altered their form and relations. As previously stated, when viewed from above, these enclose a deep fossa at their cephalic end, blending caudally in the sagittal plane to form the ridge-like crest for the urethral plate. The middle lateral folds have developed so as to be relatively long, being now continuous caudally with the lateral expansion of the sinus wall in the region of the ostium uro-

genitalis. The most distinctive change, however, is noticed in the lower lateral folds. These, though still the least conspicuous of the three sets of folds, have increased in length and elevation. The sinus lumen of this region presents a distinct difference from that found in Embryo 15. The lumen has invaded the upper and middle lateral folds, but the plate between the middle and lower folds is still solid, while in the region of the lower folds, there is a narrow lumen, blind at its cephalic end, but opening independently into the urogenital sinus.

The epithelial buds which form the anlagen of Bartholin's glands have the same relative positions as in younger stages (*m.vs.gl.*). Measured on the model, these buds are situated 1.2 mm. caudal to the point of junction of the Müllerian duct with the urogenital sinus, and spring from the cephalic portion of the middle lateral fold. The bud on the left side has a length of 120 μ, and presents a short, solid side bud at its distal end. In the middle third of its length, a loosening of the central cells suggests the beginning of a lumen. The bud on the right side has a length of 150 μ, presenting an expanded knob-like end, probably the anlage of side branches. A narrow lumen is present, just proximal to this expanded end; this lumen is surrounded by a layer of quite regular cells of a compressed cuboidal shape. In this embryo, both gland buds extend obliquely laterad and dorsally in the general direction of the middle lateral fold.

Embryo 48 is a female embryo of 48 mm. crown-breech length, and was not modelled. It presents the same general arrangement of lateral folds as described for Embryo 18. The lower lateral folds are distinct, and possess a narrow lumen which no longer ends blindly at its cephalic end, but here communicates with the lumen of the urogenital sinus. On the right side, the gland anlage passes through seven sections of 20 μ thickness; on the left side, through three such sections. However, the real difference in length of the two gland anlagen is not so great as this would seem to indicate, as the sections are not cut parallel to the mid-plane, and the left gland anlage is consequently cut very obliquely. The gland buds are still solid, with no evidence of branching.

Embryo 49 is a female embryo of 47 mm., crown-breech length, and was not modelled. The lateral urogenital sinus folds, as also the gland anlagen for Bartholin's glands, present the same general relations as in Embryos 48 and 18. The gland bud on the right side passes through eight sections having a thickness of 15 μ. The bud on the left side was very obliquely cut and loosened from the surrounding mesenchyme, so that its length was not determined.

Embryo 23, a female embryo having a crown-breech length of 60 mm., represents the oldest stage modelled. This model, as seen from the left side, is shown in figure 4. The model shows the downward (caudal) projection of the clitoris anlage, characteristic of this stage. When compared with the three preceding embryos, it is seen that the clitoris has become relatively, though not absolutely, smaller. A well-defined sulcus coronarius glandis is present, as also a deep sulcus nympho-labialis, bounding the base of the clitoris laterad. The urogenital sinus opens externally by two ostia; the larger one near the sulcus coronarius, the smaller one at the base of the clitoris. Externally, the two ostia are united by a deep groove. A continuation of this groove leads toward the anus, disappearing at about the middle of the perineum. The mesonephric ducts have degenerated to such an extent that they are incomplete on both sides.

The utero-vaginal canal (Müllerian tubes) is well developed, though its lumen does not appear to have joined that of the urogenital sinus. At the place of its fusion with the urogenital sinus, there may be observed, in the model, projections of the sinus epithelium, regarded as the anlagen of the paraurethral glands of Skene; three are to be observed on the right side, two on the left.

On each side, all of the three lateral folds have extended cephalad so as to reach the region of the utero-vaginal canal. In this embryo, the folds are complicated by the appearance of secondary folds. The upper lateral folds present each a secondary fold extending caudad to meet the middle lateral fold. The middle folds also present secondary folds, beginning just below

the anlagen of Bartholin's glands, and extending caudad. It seems possible to relate this model with the account given by R. Mayer, quoted in preceding pages of this communication. This observer has described five lateral folds or rays. Of the three

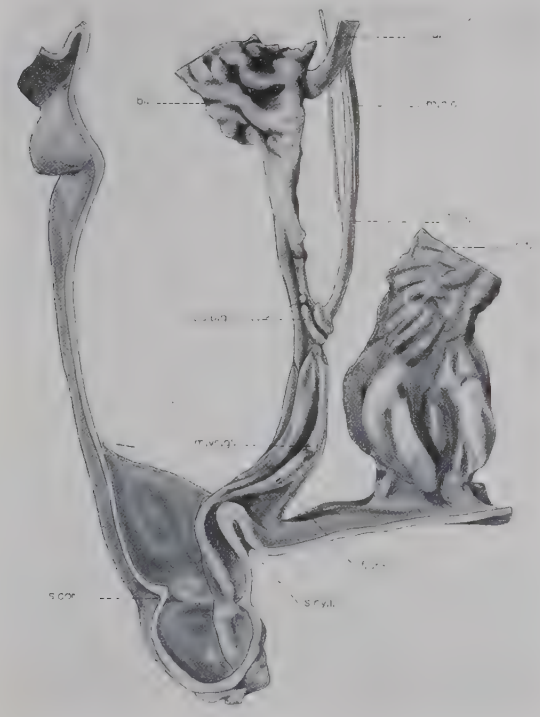

Fig. 4 Model of epithelial portion of urogenital system of human Embryo 23 (Huber collection); female, 60 mm. crown-breech length. × 15.

primary lateral folds here described, the upper, with a secondary fold imperfectly developed, seems to correspond with Mayer's first and second rays; the middle lateral fold as here designated, with its secondary fold, forms the third and fourth rays of Mayer's account; the lower fold corresponds with his fifth ray.

In Embryo 23, the gland buds forming the anlage of Bartholin's glands are shown in figure 4 at *m.vs.gl.* They arise from the middle lateral fold, 1.2 mm. from the caudal end of the utero-vaginal canal, extending from this fold obliquely laterad and dorsad. The gland bud on the left side has a length of 200 μ; on the right side, of 240 μ. Both gland buds show a knob-like end, with a slight constriction proximal to the terminal enlargement. The end of the left gland bud shows partial division into four branches, so that the cross section of this portion resembles a shamrock leaf; there is as yet, no mesenchyme separating the anlagen of the branches. The neck or stalk of this gland bud presents an interrupted lumen. Each of the branch anlagen shows a compact arrangement of the cells at the periphery, with loosely arranged central cells, preluding a lumen. The gland bud on the right side is similar to that on the left, except that only three branches are indicated, and one of these is completely surrounded by mesenchyme. Both gland anlagen are surrounded by dense mesenchyme, the beginning of a capsule. In the region of the gland anlagen, the sinus lumen has invaded the secondary fold found between the middle and lower lateral folds. The independent lumen of the lower fold was not to be observed in this embryo.

The figures of the models seem to portray the relations and extent of the lateral folds of the urogenital sinus so clearly, as also the anlagen of Bartholin's and Cowper's glands, that extended description was deemed unnecessary. The following summary and conclusions seem warranted.

SUMMARY AND CONCLUSIONS

1. Human embryos, both male and female, of the ages studied in this investigation, 3 to 6 cm. crown-breech length, present three pairs of lateral folds on the wall of the urogenital sinus. In the younger stages, these folds extend from the ostium urogenitalis to a point about halfway to the place of entrance of the mesonephric ducts into the urogenital sinus. In the older stages, they extend more cephalad; in the 6 cm. female embryo reconstructed, to the caudal end of the utero-vaginal canal.

2. These three folds first appear as solid epithelial ridges, symmetrically arranged on the two sides of the urethral plate. Keibel's models would indicate that they do not appear until the embryo has reached a length of more than 28 mm.

3. The upper lateral folds are at first the more prominent; later the middle lateral folds are relatively larger. The lower lateral folds remain inconspicuous.

4. A male embryo of 5 to 6 cm. length was not available, but the figures of Lichtenburg, Van der Broek, and other investigators would indicate that in the male, these folds become obliterated. The model figured by Broman (fig. 397) of a 6 cm. male embryo, does not show clearly whether lateral folds are present or not.

5. The anlagen of Bartholin's and Cowper's glands may be first recognized in embryos having a crown-breech length of 3 cm., as solid epithelial buds arising from the middle lateral fold near its cephalic end; in the younger stages extending laterad, in slightly older stages extending obliquely laterad and dorsad.

6. When the embryo has reached a crown-breech length of about 4.5 cm., the distal end of the gland bud presents a knob-like end with a narrower proximal portion in which a lumen is preluded. After attaining a crown-breech length of 5 to 6 cm., evidence of distal branching of the gland anlage may be observed.

7. The development of the glands on the two sides is not symmetrical, neither as to time of anlage, nor as to extent of development. This table 2 may serve to show.

TABLE 2

CATALOGUE NO.	CROWN-BREECH LENGTH IN MM.	LENGTH OF GLAND AND ANLAGEN, LEFT SIDE, IN μ	LENGTH OF GLAND AND ANLAGEN, RIGHT SIDE, IN μ
47	32		15
15	30	60	50
17	39	50	90
18	45	150	120
48	48	140	60
49	47	120	?
23	60	240	200

In conclusion, I desire to express my sincere thanks and appreciation to Professor Huber, who, in addition to suggesting the problem, has given me material aid at every step in the making of the reconstructions and in their interpretation.

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VOLUMETRIC DETERMINATIONS OF THE PARTS OF THE BRAIN IN A HUMAN FETUS 156 MM. LONG (CROWN-RUMP)

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In the present communication there is reported a study of the volume of the main divisions of the brain as they are found in a fetus about four months old. The work was undertaken as a step in the history of the growth of the individual parts of the brain under the premise that a knowledge of their volume priority would indicate in a general way the functional priority of these parts. By means of the wax-plate reconstruction method it is possible to make an accurate enlarged model of the brain that can be separated into its chief component parts. Since such a model is made of wax of a uniform composition the relation by volume and by weight of the different parts can be determined both as to each other and as to the brain as a whole. This same method was used in determining the volume of the different parts of the opossum brain, by Professor Streeter and by Mr. H. A. Tash, who reported their results at the meeting of the American Association of Anatomists at Ithaca.[1]

The brain measured was taken from a male fetus measuring 156 mm. crown-rump, and 201 mm. total, length. The head measurements were: Bitemporal, 48 mm.; occipito-frontal, 58 mm. These measurements were made on the fresh specimen. Its weight was 296 grams. The specimen was preserved in 10 per cent formalin, the skull having been opened to facilitate the penetration of the fixative. Subsequently the brain was removed, embedded in celloidin and prepared in serial sections 50 μ thick,

[1] Streeter, G. L., 1911, Volumetric analysis of the brain of the opossum. Proc. Amer. Assoc. Anat.; Anat. Rec., vol. 5, p. 91.

every other section saved and stained with alum-cochineal. From this series a model was made enlarged five diameters after the well known Born method. Serial drawings were made with a projection apparatus on papers which were then incorporated in wax plates of such a thickness that the enlargement in all planes was the same (× 5). The drawings were then cut out from the plates and filed. This gave a model of the whole brain with the ventricles removed. The plates were then gone through a second time and the various parts cut away from each other so that their individual weights and volumes could be separately determined. It was found that this could be done with considerable accuracy, and having the stained sections as a guide, it would have been possible to have carried the subdivisions further. But, having in mind both younger and older stages, it was decided that the adopted subdivision would prove most practical in the end. The results are given in table 1. In the first column of the table is given the weight in grams of the whole model and of its parts. In the second column is given the percentage of the total weight formed by each part, which would hold true for

TABLE 1

PARTS	MODEL WGT. IN GMS.	PER CENT OF TOTAL WGT.	MODEL VOL. IN CC.	ACTUAL VOLUME
Rhombencephalon	72.135	4.973	80.565	0.644
Medulla and pons	32.325	2.228	36.500	0.292
Cerebellum	39.810	2.744	44.065	0.352
Mesencephalon	20.900	1.441	23.659	0.189
Diencephalon (inc. epiphysis)	69.761	4.809	78.970	0.631
Telencephalon	1287.673	88.776	1457.658	11.661
Basal ganglia	110.610	7.625	125.210	1.001
Caudate nucleus (inc. parolf. body and amygdaloid nucleus)	73.150	5.043	82.805	0.662
Putamen	33.161	2.286	37.538	0.300
Globus pallidus	4.299	0.296	4.867	0.039
Archipallium	33.865	2.334	38.341	0.306
Fornix and hippocampus	26.075	1.797	29.522	0.236
Paraterminal body	5.815	0.401	6.583	0.052
Olfactory bulbs	1.975	0.136	2.236	0.017
Neopallium	1143.198	78.815	1294.100	10.345
Total brain	1450.468	100.000	1641.929	13.135

the actual brain just as for the model. In the third column is given the volume in cubic centimeters of the whole model and of its different parts. Instead of determining the volume of each part separately it was found more practical to determine the specific gravity of the wax plates and then calculate the volumes from the weights given in the first column. In the last column is given the volume of the brain itself and of its parts. This was obtained by dividing the volume of the model by the amount of the enlargement, i.e., the cube of five diameters. It is to be remembered that this is the volume of the brain after it has been embedded and prepared in serial sections. The volume of the fresh brain could be obtained only by calculating the amount of shrinkage the specimen experienced in this process.

The subdivisions that were used follow as far as possible the embryological subdivisions adopted by His. Their boundaries could in most cases be determined by the cell structure of the sections. In some cases it was necessary to depend on the surface configuration of the model. The landmarks utilized in carrying out this subdivision are herewith detailed:

Rhombencephalon. This was separated from the spinal cord as nearly as possible at a point post cephalic to the first cervical nerve. The cephalic boundary was determined by a plane just skirting the inferior colliculus and passing out ventrally just in front of the pons. Laterally this plane passes just in front of the brachium connecting the cerebellum and pons.

Cerebellum. This is plainly demarcated by its surface outline, while the pons is determined more by its internal structure, the main characteristic being the densely massed nuclei. The cerebellum at this time consists of a well fissured vermis and the two lateral lobes which are fissured dorsally but are still smooth ventrally. In removing it the floccular margin was included and also the brachium pontis on each side to the point at which it meets the pons. The removal of the cerebellum leaves the medulla and pons, whose weight and volume are given together.

Mesencephalon. The caudal limit of the mesencephalon is the same as the plane marking the cephalic border of the rhombencephalon, which has already been given. Its cephalic limit is a

wedge-shaped plane that projects in between the masses of the diencephalon. At the median line its boundary is marked dorsally by the posterior commissure and ventrally by a point post caudal to the mammilary bodies. From this median line the plane of division on each side extends backward so as to include the red nucleus with the midbrain and comes to the surface at a groove marking the antero-lateral margin of the superior colliculus. Owing to the advanced development of the colliculi and the retarded development of the peduncular portion, the mesencephalon is V-shaped as regards its ventral aspect, as well as its cephalic boundary.

Diencephalon. Its separation from the mesencephalon we have already indicated. From the telencephalon it is separated bilaterally by the internal capsule, and a sharp line of demarcation on the surface is afforded by the stria terminalis. Ventrally where this is not present the line of division is continued along the anterior margin of the optic tract. By this manner of subdivision there is comprised in this portion the optic tract and thalamus including the habenular nuclei and epiphysis and also the whole hypothalamus with the exception of the hypophysis, which had been removed.

Telencephalon. This includes all the remainder of the brain. It was subdivided into three main divisions as follows:

Basal ganglia. At the end of the fourth month these structures are clearly defined and bear a relation that closely approximates the adult. The putamen and globus pallidus are easily recognized in transverse sections. As for the lamina of capsule fibers that surround them, the incisions were made half-way, so that part of the fibers would go with the globus pallidus and part with the caudate nucleus. The caudate nucleus throughout its greater extent is likewise clearly defined. At its head and tail ends, however, it is complicated by fusing with the parolfactory body and amygdaloid nucleus respectively. On this account these latter were included with it.

Archipallium. This includes, in the first place, the olfactory bulbs, which were removed at a transverse line at the point where

they become free from the brain wall. This corresponds to both the bulb and stalk of the adult. The paraterminal body includes the gray substance where the olfactory bulb is attached and the region of the future septum pallucidum and the pillar of the fornix, which could not be easily separated from it. The remainder of the archipallium is made up of the body of the fornix and its fimbricated extension into the hippocampus. The hippocampus is easily recognized by its histological structure and by the way it bulges into the lateral ventricle. With it was included the dentate fascia and the uncinate body. The corpus callosum was included with the neopallium.

Neopallium. This includes the remainder of the telencephalon and represents what we know in the adult as the convoluted cortex, together with the subjacent white matter and includes the corpus callosum, as we have just pointed out.

In conclusion I wish to acknowledge the courtesy of Professor Streeter, who kindly put the resources of the Anatomical Laboratory of the University of Michigan at my disposal for the purpose of this investigation, and gave me many helpful suggestions as the work progressed.

BOOKS RECEIVED

The receipt of publications that may be sent to any of the five biological journals published by The Wistar Institute will be acknowledged under this heading. Short reviews of books that are of special interest to a large number of biologists will be published in this journal from time to time.

A LABORATORY MANUAL AND TEXT-BOOK OF EMBRYOLOGY. By Charles W. Prentiss, A.M., Ph.D., Professor of Microscopic Anatomy in the Northwestern University Medical School, Chicago. Octavo, 400 pages, 368 illustrations, many of them in colors. Philadelphia and London: W. B. Saunders Company, 1915.

Preface. This book represents an attempt to combine brief descriptions of the vertebrate embryos which are studied in the laboratory with an account of human embryology adapted especially to the medical student. Prof. Charles Sedgwick Minot, in his laboratory textbook of embryology, has called attention to the value of dissections in studying mammalian embryos and asserts that "dissection should be more extensively practised than is at present usual in embryological work. . . ." The writer has for several years experimented with methods of dissecting pig embryos, and his results form a part of this book. The value of pig embryos for laboratory study was first emphasized by Professor Minot, and the development of my dissecting methods was made possible through the reconstructions of his former students, Dr. F. T. Lewis and Dr. F. W. Thyng.

The chapters on human organogenesis were partly based on Keibel and Mall's Human Embryology. We wish to acknowledge the courtesy of the publishers of Kollmann's Handatlas, Marshall's Embryology, Lewis-Stöhr's Histology and McMurrich's Development of the Human Body, by whom permission was granted us to use cuts and figures from these texts. We are also indebted to Prof. J. C. Heisler for permission to use cuts from his Embryology, and to Dr. J. B. De Lee for several figures taken from his Principles and Practice of Obstetrics. The original figures of chick, pig and human embryos are from preparations in the collection of the anatomical laboratory of the Northwestern University Medical School. My thanks are due to Dr. H. C. Tracy for the loan of valuable human material, and also to Mr. K. L. Vehe for several reconstructions and drawings.

C. W. Prentiss.

Northwestern University Medical School,
Chicago, Ill., January, 1915.